

# THORNY DEVIL NANOFIBERS: THE WAY TO COOLING RATES OF THE ORDER OF 1 KW/CM<sup>2</sup>

A. L. Yarin<sup>1,2</sup>

<sup>1</sup>Department of Mechanical and Industrial Engineering,

University of Illinois at Chicago, 842 W. Taylor Str.

Chicago, IL 60607, USA

<sup>2</sup>Center for Smart Interfaces, Technische Universität Darmstadt

Petersenstr. 32, 64287 Darmstadt, Germany

A novel method of enhancement of drop and spray cooling for microelectronic, optical and radiological elements and server rooms, which require extremely high heat fluxes, is discussed in its hydrodynamic experimental and theoretical aspects. The key idea of the method is to cover the heat transfer surfaces with electrospun or solution-blown nonwoven polymer and metalized nanofiber mats. The experiments revealed that drop impacts on nanotextured surfaces of nanofiber mats produce spreading similar to that on the impermeable surfaces. However, at the end of the spreading stage the contact line is pinned and drop receding is arrested. All the mats, which are statically superhydrophobic due to air entrapped in their pores (90-95% porosity), appeared to be dynamically permeable for water drops. The enhanced efficiency of drop cooling in the presence of nanofiber mats observed experimentally results from full elimination of receding and bouncing of the drops, characteristic of the current spray cooling technology. Therefore, in the present case drops evaporate completely, and the large cooling potential associated with the latent heat of water evaporation is more fully exploited. This is paradoxical: the best cooling can be provided by a "furry overcoat"! Moreover, metal-plated thorny devil-like nanofiber mats produced cooling rates in the range of 0.4-0.6 kW/cm<sup>2</sup>.

The hydrodynamic aspects of the dynamic wettability phenomenon (a forced transition from the Cassie-Baxter to Wenzel state) discovered in this work involve the analysis of flow inside an instantaneously stopped droplet, which channels its kinetic energy into a tiny pore in the nanofiber mat similarly to formation of shaped-charge jets. This analysis in planar problem is based on the application of the Cauchy formula, which in the present case inevitably reduces to Poisson's integral formula for the upper half-plane. In the axisymmetric problem the theoretical analysis employs the Fourier method for problems with continuous spectrum. The accompanying moisture impregnation process inside nanofiber mats is studied experimentally and analyzed in the framework of the parabolic equations for moisture transport.

Acknowledgement: Partial support of this work by NSF (NIRT CBET-0609062 and CBET-0966764) and NASA (NNX10AR99G) is greatly appreciated.